Chapter 1
Introduction

This document presents the results of a cleaner technologies substitutes assessment (CTSA) of seven technologies for performing the "making holes conductive" (MHC) function during the manufacture of printed wiring boards (PWBs). MHC technologies are used by PWB manufacturers to deposit a seed layer or coating of conductive material into the drilled through-holes of rigid, multi-layer PWBs prior to electroplating. The technologies evaluated here are electroless copper, carbon, conductive polymer, graphite, non-formaldehyde electroless copper, organic-palladium, and tin-palladium. Chemical and process information is also presented for a conductive ink technology, but this technology is not evaluated fully.[1]

For the purposes of this evaluation, the non-conveyorized electroless copper process is considered the baseline process against which alternative technologies and equipment configurations (e.g., non-conveyorized or conveyorized) are compared. This CTSA is the culmination of over two years of research by the U.S. Environmental Protection Agency (EPA) Design for the Environment (DfE) PWB Project and the University of Tennessee (UT) Center for Clean Products and Clean Technologies on the comparative risk, performance, cost, and natural resource requirements of the alternatives as compared to the baseline.

The DfE PWB Project is a voluntary, cooperative partnership among EPA, industry, public-interest groups, and other stakeholders to promote implementation of environmentally beneficial and economically feasible manufacturing technologies by PWB manufacturers. Project partners participated in the planning and execution of this CTSA by helping define the scope and direction of the CTSA, developing project workplans, donating time, materials, and their manufacturing facilities for project research, and reviewing technical information contained in this CTSA. Much of the process-specific information presented here was provided by chemical suppliers to the PWB industry, PWB manufacturers who responded to project information requests, and PWB manufacturers who volunteered their facilities for a performance demonstration of the baseline and alternative technologies.

Section 1.1 presents project background information, including summary descriptions of the EPA DfE Program and the DfE PWB Project. Section 1.2 is an overview of the PWB industry, including the types of PWBs produced, the market for PWBs, and the overall PWB manufacturing process. Section 1.3 summarizes the CTSA methodology, including a discussion of how technologies were selected for evaluation in the CTSA, the boundaries of the evaluation, issues evaluated, data sources, and project limitations. Section 1.4 describes the organization of the remainder of the CTSA document.

[1] Only limited analyses were performed on the conductive ink technology for two reasons: 1) the process is not applicable to multi-layer boards, which were the focus of the CTSA; and 2) sufficient data were not available to characterize the risk, cost, and energy and natural resources consumption of all of the relevant process steps (e.g., preparation of the screen for printing, the screen printing process itself, and screen reclamation).

1.1 PROJECT BACKGROUND

The PWB is the underlying link between semiconductors, computer chips, and other electronic components. Therefore, PWBs are an irreplaceable part of many "high-tech" products in the electronics, defense, communications, and automotive industries. PWB manufacturing, however, typically generates a significant amount of hazardous waste, requires a substantial amount of water and energy, and uses chemicals that may pose potential environmental and health risks.

To address these issues, the PWB industry has been actively seeking to identify and evaluate cleaner technologies and pollution prevention opportunities. However, many PWB manufacturers are small businesses that cannot afford to independently develop the data needed to evaluate new technologies and redesign their processes. The DfE PWB Project was initiated to develop that data, by forming partnerships between the EPA DfE Program, the PWB industry, and other interested parties to facilitate the evaluation and implementation of alternative technologies that reduce health and environmental risks and production costs. The EPA DfE Program and the DfE PWB Project are discussed in more detail below.

1.1.1 EPA DfE Program

EPA's Office of Pollution Prevention and Toxics created the DfE Program in 1991. The Program uses EPA's expertise and leadership to facilitate information exchange and research on risk reduction and pollution prevention opportunities. DfE works on a voluntary basis with small- and mostly medium-sized businesses to evaluate the risks, performance, costs, and resource requirements of alternative chemicals, processes, and technologies. Additional goals of the program include:

- Changing general business practices to incorporate environmental concerns.
- Helping individual businesses undertake environmental design efforts through the application of specific tools and methods.

The DfE Program catalyzes voluntary environmental improvement through stakeholder partnerships. DfE partners include industry, trade associations, research institutions, environmental and public-interest groups, academia, and other government agencies. By involving representatives from each of these stakeholder groups, DfE projects gain the necessary expertise to perform the project's technical work and improve the quality, credibility, and utility of the project's results.

1.1.2 DfE Printed Wiring Board Project

The DfE PWB Project is a voluntary, cooperative partnership among EPA, industry, public-interest groups, and other stakeholders to promote implementation of environmentally beneficial and economically feasible manufacturing technologies by PWB manufacturers. In part, the project is an outgrowth of industry efforts to identify key cleaner technology needs in electronic systems manufacturing. The results of these industry studies are presented in two reports prepared by Microelectronics and Computer Technology Corporation (MCC), an industry research consortium: *Environmental Consciousness: A Strategic Competitiveness Issue for the*

Electronics Industry (MCC, 1993) and *Electronics Industry Environmental Roadmap* (MCC, 1994).

The first study identified wet chemistry processes, such as those used in PWB fabrication, as water- and energy-intensive processes that generate significant amounts of hazardous waste. The study concluded that effective collaboration among government, industry, academia, and the public is imperative to proactively address the needs of environmental technologies, policies, and practices (MCC, 1993). As follow-up, the industry embarked on a collaborative effort to develop an environmental roadmap for the electronics industry. The roadmap project involved more than 100 organizations, including EPA, the Department of Energy, the Advanced Research Projects Agency, and several trade associations. The PWB industry national trade association, the Institute for Interconnecting and Packaging Electronic Circuits (IPC), was instrumental in developing the information on PWBs through its Environmental, Health, and Safety Committee.

The highest priority need identified for PWB manufacturers was for more efficient use, regeneration, and recycling of hazardous wet chemistries. One proposed approach to meet this need was to eliminate formaldehyde from materials and chemical formulations by researching alternative chemical formulations. Another priority need for the industry was to reduce water consumption and discharge, which can also be accomplished with alternative wet chemistries that have reduced numbers of rinse steps. Electroless copper technologies for MHC use formaldehyde as a reducing agent and consume large amounts of water.

The potential for improvement in these areas led EPA's DfE Program to forge working partnerships with IPC, individual PWB manufacturers and suppliers, research institutions such as MCC and UT's Center for Clean Products and Clean Technologies, and public-interest organizations, including the Silicon Valley Toxics Coalition and Communities for a Better Environment. These partnerships resulted in the DfE PWB Project.

Since its inception in 1994, the primary focus of the Project has been the evaluation of environmentally preferable MHC technologies. This CTSA is the culmination of this effort. The project has also:

- Identified, evaluated, and disseminated information on viable pollution prevention opportunities for the PWB industry through a review of pollution prevention and control practices in the industry (EPA, 1995a).
- Prepared several case studies of pollution prevention opportunities (EPA, 1995b; EPA, 1995c; EPA, 1996a; EPA, 1996b; EPA, 1996c).
- Prepared a summary of federal environmental regulations affecting the electronics industry (EPA, 1995d).
- Developed a summary document that profiles the PWB industry and defines and describes the typical manufacturing steps in the manufacture of rigid, multi-layer PWBs (EPA, 1995e).
- Prepared an implementation guide for PWB manufacturers interested in switching from electroless copper to an alternative MHC technology (EPA, 1997).

Future activities will include an evaluation of alternative surface finishes that can substitute for the hot-air solder leveling process.